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(71) Applicant: Haldor Topsoe A/S
2800 Kgs. Lyngby (DK)

(72) Inventors:
- Jensen, Benny Norman
3520 Farum (DK)
- Olsen, Torsten
2730 Herlev (DK)

(54) Method for determination of mass flow and density of a process stream

(57) A method for controlling mass flow of a hydrocarbon feed stream to a steam reformer said stream consisting of hydrogen and of natural gas, naphtha, off-gas, LPG, or a mixture hereof, and

molar carbon flow of a hydrocarbon feed stream to a reformer said stream consisting of hydrogen and of natural gas, naphtha, off-gas, LPG, or a mixture hereof, the molar carbon flow being determined as $F_c = C_n$ x (V/22.414) x P x (273/T) C_n being a function of density, and
molar steam carbon ratio in feed stream to a steam reformer, wherein the molar steam and carbon flows are determined as $F_{st} = (V_{st}/22.414)$ x P_{st} x $(273/T_{st})$, and $F_c = C_n$ x (V/22.414) x P x (273/T), C_n being a function of density, providing the molar steam carbon ratio $R = F_{st} / F_c$ by online measurement of mass flow and density of a process stream, comprising the steps of

- measurement of said process stream with a conventional differential pressure flow measuring element, providing a signal S' = k' x p x V^2,
- measurement of same said process stream with a conventional vortex flow measuring element, providing a signal S" = k" x V, and
- determination of the mass flow and density of process stream from signals from both said flow measuring elements by the above formulae and M = p x V, as S' / S" = k x ρ x V = k x M and S' / $(S")^2$ = k x ρ.

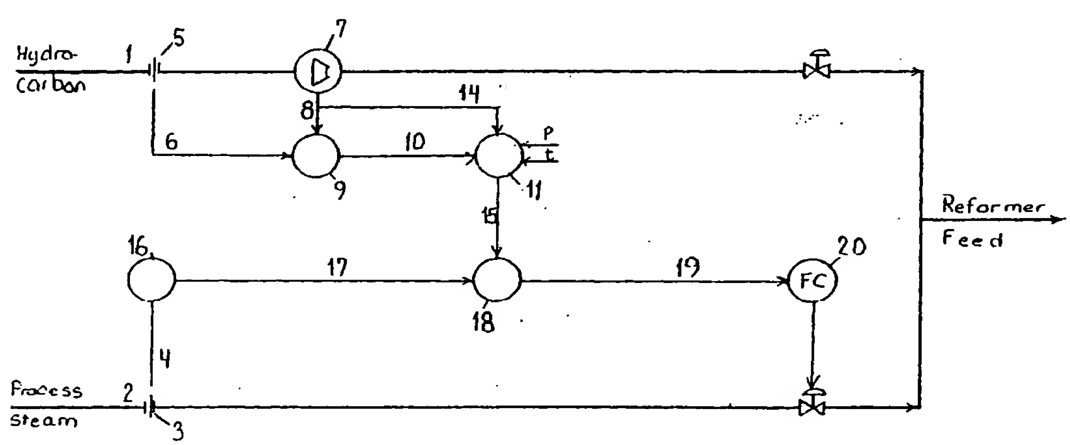

FIG 3

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$$M = \rho \times V$$

and the signal can be expressed as

$$S' = k' \times M \times V$$

The signal, S" from a vortex flow element is:

$$S" = k" \times V$$

[0017] A computing relay dividing signal S' by signal S" creates directly a mass flow signal

$$S = \frac{S'}{S"} = \frac{k' \times M \times V}{k" \times V} = k \times M$$

[0018] Alternatively, if the computing relay first squares the signal from the vortex measurement, the density is obtained:

$$S = \frac{S'}{S"^2} = \frac{k' \times \rho \times V^2}{k"^2 \times V^2} = k \times \rho$$

which again directly is related to the molecular weight, a useful parameter in some connections.

[0019] By this method, the mass flow and density can be determined at high pressure and temperature even for heavy gasses, which the measuring elements of the invention are suitable for.

[0020] The invention is particularly useful for mass flow and density measurement of the hydrocarbon feed flow to a steam reformer, where the hydrocarbon feed flow consists of two or more different process streams, and the combination can vary from one operation situation of the plant to the other.

[0021] At a certain reformer capacity the mass flow of hydrocarbon in the reformer feed is to be kept more or less constant, whereas the requirement of actual volumetric flow of a light hydrocarbon and a heavy hydrocarbon are different. This means that the mass flow must be controlled rather than the volumetric flow. At the same time, it is important that the permanent pressure drop of the flow measurements is kept low to keep energy consumption at a minimum.

[0022] Feed to a steam reformer is a mixture of steam and hydrocarbon, and the mixture must have a fixed molar ratio between steam and carbon. The molecular weight of a hydrocarbon is a good measure of the amount of carbon and at constant temperature, pressure and compressibility the molecular weight is directly related to the density. Thereby, a density measurement of a hydrocarbon feed stream to a steam reformer is a useful parameter in determining the correct steam flow.

[0023] The hydrocarbon feed to a reformer can typically be natural gas, off-gas, LPG, naphtha or mixtures hereof with addition of hydrogen or a hydrogen rich gas.

[0024] This means that in a process stream, which consists of a light hydrocarbon and a heavy hydrocarbon, a smaller change in the volumetric flow of th heavy hydrocarbon would also create a smaller change in the total volumetric flow. But this change means a relative large change in the total mass flow, which is important for the operation of the reformer. If this change is a decrement in flow, a volume flow measurement would not detect this as a severe change in hydrocarbon flow, and at unchanged firing of the reformer this could be severely overheated resulting in reduced lifetime of the tubes or even tube ruptures.

[0025] By measurement in accordance with the invention a major change in the mass flow of the hydrocarbon feed will be discovered immediately and appropriate actions can be taken in due time to avoid overheating.

[0026] Density measurement also detects chang in molecular weight immediately and the steam flow can be corrected at once.

Example 1

[0027] In case a process feed is either natural gas or naphtha, the possible feed flows of either natural gas or naphtha could be

	Natural Gas	Naphtha
Volume flow, Nm^3/h	31,430	8,698
Mass flow, kg/h	22,735	21,857

[0028] From these figures it can be seen that a volumetric flow controller maintaining 31430 Nm^3/h natural gas does not maintain 8698 Nm^3h naphtha, while a mass flow controller maintaining 22735 kg/h will also maintain the naphtha flow.

Example 2

[0029] A feed to a reformer consists of 21468 kg/h heavy naphtha and 389.3 kg/h hydrogen having the molecular weights 109.36 and 2.03, respectively, which is 4400 Nm^3/h naphtha and 4298 Nm^3/h hydrogen.

[0030] If the hydrogen flow is increased by 30%, the molecular weight of the process stream is changed from 56.32 to 49.32.

[0031] A flow controller receiving the signal from a pressure differential flow element will change the flow to 9295 Nm^3/h corresponding to a signal identical to the original signal, i.e. maintaining ρV^2.

[0032] In this way the naphtha mass flow is decreased 7%. A flow controller receiving the signal from a mass flow measurement will maintain the total of 21857.3 kg/h, which now correspond to 21357kg/h naphtha, i.e. a decrease of 0.5% only.

[0046] The steam carbon ratio is

$$R = F_{st} / F_c.$$

Claims

1. A method for controlling mass flow of a hydrocarbon feed stream to a steam reformer said stream consisting of hydrogen and of natural gas, naphtha, off-gas, LPG, or a mixture hereof, and molar carbon flow of a hydrocarbon feed stream to a reformer said stream consisting of hydrogen and of natural gas, naphtha, off-gas, LPG, or a mixture hereof, the molar carbon flow being determined as $F_c = C_n \times (V/22.414) \times P \times (273/T)$ C_n being a function of density, and molar steam carbon ratio in feed stream to a steam reformer, wherein the molar steam and carbon flows are determined as $F_{st} = (V_{st}/22.414) \times P_{st} \times (273/T_{st})$, and $F_c = C_n \times (V/22.414) \times P \times (273/T)$, C_n being a function of density, providing the molar steam carbon ratio $R = F_{st} / F_c$ by online measurement of mass flow and density of a process stream, comprising the steps of

   - measurement of said process stream with a conventional differential pressure flow measuring element, providing a signal $S' = k' \times \rho \times V^2$,
   - measurement of same said process stream with a conventional vortex flow measuring element, providing a signal $S'' = k'' \times V$, and
   - determination of the mass flow and density of process stream from signals from both said flow measuring elements by the above formulae and $M = \rho \times V$, as $S' / S'' = k \times \rho \times V = k \times M$ and $S' / (S'')^2 = k \times \rho$.

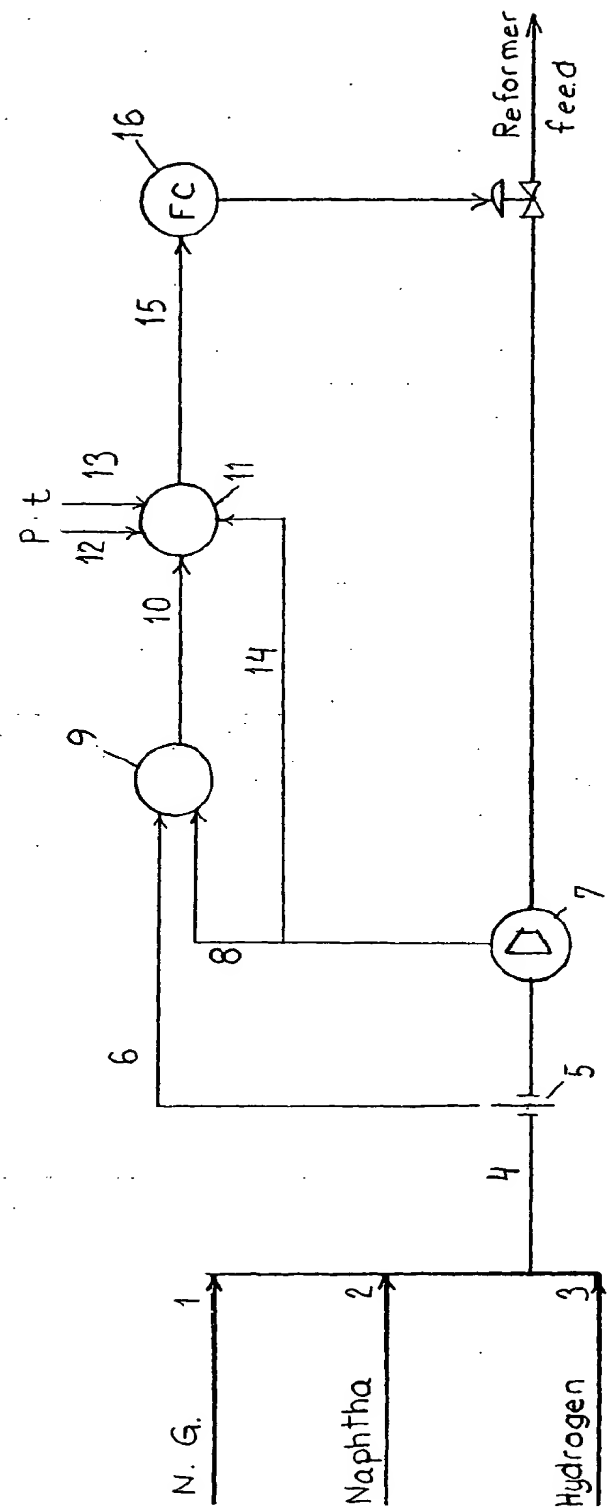
N. G.
Naphtha
Hydrogen
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
P.t
FC
Reformer
feed

FIG 2